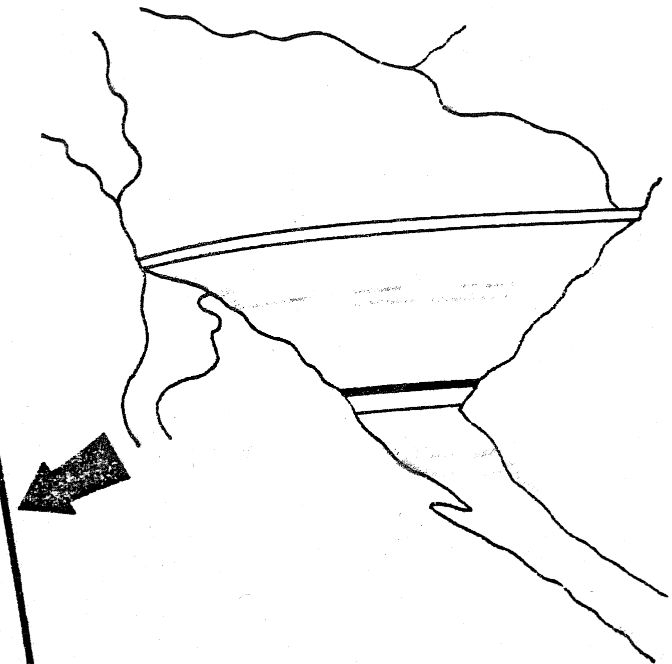
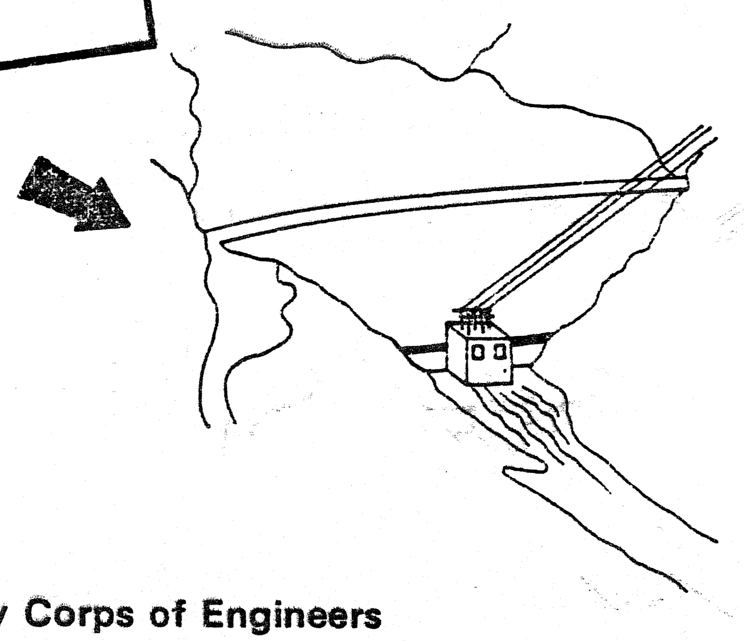
# Feasibility Studies For Small Scale Hydropower Additions



## A Guide Manual



U.S. Army Corps of Engineers

# Feasibility Studies For Small Scale Hydropower Additions

## A Guide Manual

July 1979

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# PREFACE

The manual provides technical data and procedural guidance for the systematic appraisal of the viability of potential small hydropower additions. It focuses upon the concepts, technology, and economic and financial issues unique to small hydropower additions. The manual, designed to aid in the performance of reconnaissance studies (should a feasibility study be performed?) and feasibility studies an investment commitment be made?), was developed for use by public agencies (federal, state, and local), public and private utilities, and private investors.

The manual is comprised of six volumes: Technical Guide, Volume I, overviews the investigation process, provides implementation guidance, and documents case study applications; Economic and Financial Analysis, Volume II, includes criteria and procedures for marketing and valuing power output, determining economic feasibility, and analyzing financial requirements and issues critical to implementation; Hydrologic Studies, Volume III, describes investigations necessary to evaluate the hydrologic integrity of the existing facility and to estimate the power potential of the hydropower addition; Existing Facility Integrity, Volume IV, provides guidance for assessing the ability of a site to safely accommodate a power addition; Electromechanical Features, Volume V, describes selection criteria and performance characteristics of small hydro generation and ancillary equipment; and Civil Features, Volume VI, provides preliminary design and cost guidelines for the civil features of power additions. A glossary of hydropower terms follows Volume VI.

The manual preparation was the responsibility of the Hydrologic Engineering Center, Bill S. Eichert, Director. The U.S. Army Corps of Engineers Institute for Water Resources sponsored the manual preparation as a complementary task to the management of the National Hydropower Plan activities for which they are responsible. The Department of Energy provided funding support under their small scale hydro commericalization program. The preparation of the manual was a joint effort by staff of the Hydrologic Engineering Center and several private contractors. Mr. Darryl W. Davis of the Hydrologic Engineering Center was the principal-in-charge. The Technical Guide, Volume I, was written by Mr. Davis aided by Mr. Brian W. Smith of his staff. The Hydrologic Studies, Volume III, was written by Mr. Dale R. Burnett of the Hydrologic Engineering Center aided by his staff. The remaining volumes were prepared under contract to the Hydrologic Engineering Center. The Economic and Financial Analysis, Volume II, was prepared by Development and Resources Corporation, Sacramento, CA. Mr. David C. Auslam, Jr. was the project manager, Mr. Mark Henwood was the principal author, and Mr. James Gibbs and Mr. Norman Sturn served as consultants. Also prepared by Development and Resources Corporation was the Great Falls Hydroelectric Project Case Study, appended to Volume I, with major technical contributions by Mr. Clarence Korhonen. The Existing Facility Integrity, Volume IV, was prepared by W. A. Wahler & Associates, Palo Alto, CA. Mr. Forrest W. Gifford was the project manager and Mr. Clifford S. Cortright served as a consultant. The Electromechanical Features, Volume V, and the Civil Features, Volume VI, were prepared by Tudor Engineering Company, San Francisco, CA. Mr. David C. Willer was the project manager for both volumes, and Mr. Donald J. Guild and Mr. Horace E. Burrier were the principal investigators for Volume V and Volume VI, respectively. Also prepared by Tudor Engineering Company was the Rollins Power Project Case Study, appended to Volume I.

# TECHNICAL GUIDE

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# SECTION 1
# INTRODUCTION AND OVERVIEW

## Scope and Purpose of Manual

The recent focus on our national energy resources has generated significant renewed attention in hydroelectric power development. In particular, recent investigations (Federal Power Commission, 1976; Trisco, 1975) that analyze the undeveloped hydroelectric potential at existing reservoir sites indicate that detailed studies of many sites are warranted. An attractive feature of these sites is that many of the difficulties in developing new power sites have already been dealt with (e.g., an impoundment exists). Another finding (McDonald, 1977) was that the need exists for updating and refining analysis data and methods, especially for small power additions of 15,000 kilowatts or less. This manual, referred to hereafter as the "guide manual" or simply "manual" has been prepared to meet this need.

The guide manual is designed for use by public agencies (federal, state, local, and special districts), public and private utilities, private investors, and research and educational institutions. It is a procedural guide that includes technical data and methods suitable for the systematic appraisal of potential small hydropower additions to existing facilities. It focuses upon the concepts, technology, and economic and financial issues unique to small hydropower additions.

The manual is comprised of six volumes: Volume I, "Technical Guide," overviews the investigation process, provides implementation guidance, and documents case study applications; Volume II, "Economic and Financial Analysis," includes criteria and procedures for marketing and valuing power output, determining economic feasibility, and analyzing financial requirements and issues critical to implementation; Volume III, "Hydrologic Studies," describes investigations necessary to evaluate the hydrologic integrity of the dam and to estimate the power output of plant additions; Volume IV, "Existing Facility Integrity," provides guidance for assessing the ability of a site to safely accommodate a power addition; Volume V, "Electromechanical Features," describes selection criteria and performance characteristics of small hydro generation and ancillary equipment; and Volume VI, "Civil Features," provides preliminary design and cost guidelines for the civil features of power additions.

A glossary of hydropower terms is included as an appendix. The terms and definitions were derived from hydropower industry sources, and textbooks. Where conflicts and uncertainty in definitions were found, the prevailing common usage was adopted.

## Overview - Guide Manual Volumes

**Volume I - Technical Guide**. This volume defines small hydropower and discusses the issues and technology associated with power additions to existing impoundments. The volume provides an overview of the manual, presents the purpose, concept, and configuration of the manual, and describes the components of a feasibility study and their interrelationships. Feasibility investigations are characterized as a continuum that begins with generalized resource assessments, such as the many resource assessments underway across the U.S., and concludes when construction is initiated. Decision points exist at several critical stages. The guide manual provides guidance for the reconnaissance stage (should a feasibility study be initiated?) and the feasibility stage (should an implementation commitment be made?) decision points. It is recognized that subsequent events could alter the implementation decisions; such as undiscovered site problems of integrity, foundation competence; financing difficulties (problems in bond marketing for instance); or unfavorable bid openings. The manual is quite comprehensive and following its guidance should significantly minimize the likelihood of unforeseen problems in late implementation stages.

The volume includes a description of major task elements needed to perform the reconnaissance and feasibility studies. Emphasis is placed on the facts that the planning studies need to be performed in considerable detail, site specific conditions are important, and investigation costs must be kept to a minimum. The contents of the other five volumes are described and their use conceptually integrated into the analysis process.

Included as exhibits to the "Technical Guide" are two case studies of existing projects, one from the far west area that is nearing construction completion and start up and one from the northeast that is in the licensing stage. The case studies reformulate the two projects following the data and guidance in the manual and serve both as a test of the manual and illustrated examples of manual use.

**Volume II - Economic and Financial Analysis**. This volume provides a documented procedure for performing the economic and financial studies necessary for a feasibility determination. The three major subjects covered in the volume are the market analysis, the economic feasibility determination, and the financial feasibility determination. The perspectives appropriate for public and private utilities and private investors are considered.

The market analysis section discusses the factors governing marketability of capacity and energy as related to the unique nature of small hydropower, the procedure used to determine the energy and capacity values for small hydropower, and the marketing arrangements applicable to small hydropower. The market analysis takes the stance of an owner/project sponsor performing the analysis so that the benefits and costs of the sale of power from a small hydro project can be evaluated.

The economic feasibility section clearly distinguishes economic feasibility from financial analysis. Economic feasibility is defined as positive when project benefits exceed project costs. Included is a discussion as to the appropriate perspective of the project evaluations that are performed, procedures and guidelines for arranging cost and benefit data, suggested presentation format, and a description of economic feasibility determination. Concepts for including cost escalation (e.g., fuel costs) in the analysis are discussed.

Financial feasibility is defined as positive when it can be demonstrated that the project can secure the needed financing for implementation and that the revenue receipt pattern will provide debt service at a reasonable rate of return for loans that may be incurred. Included are procedures and guidelines for revenue and cash flow analysis, opportunities for innovation in financial and revenue arrangements with utilities and other energy institutions, alternative construction financing possibilities and financial implication of those useful in small hydropower development, and a description of financial feasibility determination. The important role of a financial advisor in project studies is presented.

**Volume III - Hydrologic Studies**. This volume describes the studies needed to determine the integrity of the existing structure during the passage of major flood events and to determine the capacity and energy potential at the site. The topics of spillway adequacy, basic streamflow development methods, and capacity and energy calculations are discussed in major sections. The spillway is the safety valve of a dam and is the primary facility protecting it from failing by overtopping due to flooding. The current criteria for spillway performance as a function of reservoir capacity, dam height, and vulnerability of downstream areas that has emerged from dam safety studies by the Corps of Engineers are described. The hydraulic characteristics of spillways and outlet works are described and technical references for analysis procedures included. Flow-exceedance frequency and hydrograph analysis techniques to enable calculation of the range of events needed for spillway evaluation are presented.

The degree to which streamflow records are short, contain gaps, are poorly recorded, or to which changes in operating policy have occurred or are possible in the future, determines the complexity of the task and effort needed to assemble a representative record. Reconstruction of a long period of record by simulation of the hydrologic process and operation of the project is the most accurate and time consuming analysis technique, and adaptation of processed synthetic data from generalized studies such as flow duration curves requiring minimal effort, can be used but could be of poor quality. The appropriate strategy for a small hydro study will certainly vary from site to site but is likely to be found somewhere between the two extremes. A typical situation is likely to require the use of one or more simple approaches initially and the eventual adoption of a likely representative record for more detailed analysis.

Power analysis procedures including duration curve analysis, mass inflow curves, low flow frequency, and sequential period of record routing are described and examples included. Duration curve analysis is characterized as the least exact but easiest to perform (and many times is entirely adequate) and sequential period of record routing as the most accurate (depending on the quality of the available record) but requiring the most effort. Computational aids in the form of references and computer programs are described.

**Volume IV - Existing Facility Integrity**. The volume adopts the posture that a prerequisite to serious consideration of a site for a small hydro addition is that it be capable of meeting current dam safety standards. The small hydro addition could be expected to make modest improvements to meet integrity deficiencies but would not often generate adequate benefits to "carry" significant remedial work. This observation changes if alternative financing for safety related remedial work is separately provided. The integrity volume is designed to identify early in the feasibility study, any deficiencies that might exist and thus provide a decision point for study termination. Guidance for formulating a range of suitable remedial measures is included.

The volume can by no means provide inexperienced engineers with the capability to perform definitive safety studies. The intent is to provide a strategy that will alert investigators to potential problems. Should the problems appear critical, the volume recommends terminating the power addition feasibility study and notifying appropriate state and federal authorities of the existence of the identified integrity deficiencies.

The volume classifies and describes the principal dam types (concrete, masonry, and earth and rockfill) likely to be encountered in a small hydro addition feasibility study. The appurtenant works associated with dams (spillway, outlet works, power plants, locks, and fish ladders) are described by type and function. The typical deficiencies and failure modes of dam overtopping, uncontrolled or excessive seepage, foundation instability, embankment slope instability, slope protection deterioration on embankment dams, concrete deterioration, excessive uplift pressures, spillway/outlet works failure, and erosion are described and the principal mechanism causing the deficiencies are discussed. Potential adverse effects of power additions are highlighted to alert investigators to problems that may be created by the modification of existing facilities to accommodate a power plant.

The integrity investigation is outlined as a three staged process: (1) records collection and examination, (2) supplemental data collection and analysis to support conclusions relative to integrity, and (3) formulation of repair schemes, if they prove necessary, for rehabilitation work. The elements of each stage and strategies for their performance are outlined.

**Volume V - Electromechanical Features**. The volume defines electromechanical equipment as the features and systems needed to harness the energy, both potential and kinetic, available in impounded or flowing water, to convert it to electrical energy, to control it, and to transmit it to a regional power grid. The major equipment items are the hydraulic turbine, the electric generator, and a switchyard consisting of a transformer, circuit breaker, and switch gear. Included are supporting systems which control and protect these major equipment items. Maintenance facilities such as a crane for lifting are also included in a broad definition of electromechanical equipment.

Several domestic and foreign equipment manufacturers have historically provided small turbines and are active in standardizing unit sizes and packaging relatively complete generating sets for marketing. These current trends are defined. Relaxing the need for some control and protection equipment is becoming accepted as the scaling down to small facilities takes root within the industry. Simpler low cost governors and similar items are appearing on the market. Smaller hydroelectric plants can also be designed with less flow control than larger plants. The flow of water to most turbines is controlled by a set of wicket gates. These gates are regulated by signals from the governor to control the amount of power produced. Where power control is not needed (many small plants) the gates can be eliminated and the cost of the turbine reduced by as much as 10 percent.

The volume outlines a procedural strategy for selecting and sizing the generating equipment, and includes description, cost, and performance data for Francis, Crossflow, Propeller, Tube, Bulb, Slant, and Rim turbines suitable for the range of heads and power outputs for a small plant. The common indexing parameter used among data and relationships within the electromechanical volume is the turbine throat diameter. This parameter is carried forward to the Civil Features volume (discussed next) as the indexing parameter to determine powerhouse layout dimensions and costs.

A section describing generators suitable for small hydro is included and data on dimensions and weights tabulated. Descriptive data, performance curves, and costs are likewise included for generation control and protection equipment, and switching, transmission and miscellaneous equipment.

**Volume VI - Civil Features**. The civil features of small hydropower additions are defined as site preparation works, hydraulic conveyance facilities, and powerhouse and appurtenant facilities. Site preparation includes grading, foundation excavation, drainage and erosion control, access roads and parking facilities, and construction noise abatement and dust control. Hydraulic conveyance facilities include penstocks, tunnels, canals, valves and gates, inlet and outlet works, and tailraces. Powerhouse and appurtenant facilities include all structures for the powerhouse and equipment handling facilities, foundations for both the powerhouse and switchyard, and fencing around the project area.

Civil features can at times comprise a significant component of construction cost of small hydro additions. Since major elements of the site are fixed (e.g., embankment, outlet works, spillway) it is important to approach the layout task with an open and innovative attitude. The difference between a feasible and infeasible project may be determined by the cleverness with which use is made of the existing site arrangement and features. The civil features differ from those of major hydropower plants both in scale and in substance. It is appropriate to design adequate outdoor type plants for small units and often portable lifting equipment will suffice for maintenance obviating the need for enclosing structures and fixed gantry cranes. Protection equipment can likewise often be minimized. Layout guidance, dimensions, and cost functions for the several categories of civil features are included. Descriptive text is included to alert the project investigator to circumstances in which the generalized relationships that are included are unreliable and guidance is given for developing alternative data when necessary.

Cost escalation indicies are included so that the cost data (cost data in all volumes are in July 1978 dollars) may be scaled to the base period used for the feasibility analysis. Both this volume and volume V include cost summary sheets keyed to the Federal Energy Regulatory Commission (FERC) account numbers.

**Use of Guide Manual**

The manual is designed for use by the variety of organizations and private individuals that might study small hydropower projects for feasibility. The document is a guide; not a cookbook. A structure is presented within which the majority of studies are expected to fall. A feasibility investigation of sufficient quality to provide a basis for investment decisions requires the services of qualified professional engineers.

The technical data of selection criteria and charts, physical feature layouts, and performance charts are considered adequate for both reconnaissance and feasibility studies. The cost charts are expected to be adequate for the majority (perhaps 80%) of project settings and configurations likely to be encountered. Notes alerting analysts to special conditions for which the charts would be less accurate are included. For those instances, a specific layout, preliminary design and cost estimate would probably be necessary even at the feasibility level of study.

The material in the manual should be informative to those interested in small hydro (e.g., engineers, administrators, and private enterprenuers). Most of the material is presented in common narrative terms but this should not be construed to suggest that unqualified individuals can thus perform quality studies. Several scenarios of use are envisioned. Institutions/organizations with small technical staffs are expected to find the manual adequate to guide them in preparation of a reconnaissance study and then provide an information base that would be helpful in proceeding to procure the services of qualified consultants, should the reconnaissance finding be positive. Institutions/organizations with technical staffs not experienced in small hydropower but experienced in the several technical areas involved are expected to find the manual helpful in developing capability to perform the feasibility level studies, by having available an organized set of material and guidance (including references) on small hydro. Institutions/organizations experienced in hydropower development (but perhaps not small hydro) should find the manual to be a useful reference that documents many important concepts and represents a compilation of the current state-of-the-art in small hydro.

# SECTION 2
# SMALL HYDROPOWER

## Definition

Small hydropower projects include installations that have 15,000 kilowatts (kW) or less capacity. Although the concept is not limited to additions to existing impoundments, most activities by federal, state, local agencies, and private organizations are so focused. This manual is concerned exclusively with hydropower additions to existing facilities. "Small hydro" and "low head hydro" are not synonomous even though the tendency in public statements and published literature and documents is to blur the distinction. Small hydro as defined above has been an informal breaking point used for various federal and other agency statistical tabulations and informal communications. The concept has now been defined by the Public Utility Regulatory Policies Act (PL 95-617, November 1978) to be 15 megawatts (MW) for purposes of special handling for licensing, loans, incentives, and other promotional programs. Provisions of the law specifically related to small hydro are limited to additions to existing facilities. Low head hydro is a term associated with a research and development program managed by the Department of Energy that is designed to advance the technology for generating hydropower from sites with heads of less than 20 meters (66 feet). A large number of the presently identified small hydro addition sites fall within the low head criteria. This distinction between small and low head hydro will be preserved herein for convenience in communication and consistency with existing and emerging federal and state programs.

The fundamental thesis for small hydro as a concept (apart from hydropower in general) is that the impacts of implementation (especially for an addition to an existing impoundment) are likely to be modest; thus, projects will be essentially non-controversial so that simpler license and permit granting programs are appropriate, and physical facilities can be kept simple and functional. Implementation will therefore be possible in relatively short time frames.

## Existing and Potential Development

A significant number of existing hydropower installations in the United States could be classified as small hydro. Current installed hydropower capacity is near 60 million kW in about 1,400 plants, which results in an average installed capacity of about 40 MW per plant. The latest published inventory (Federal Power Commission, 1976) lists 142 plants as having installed capacities greater than 100 MW. Deducting the sum of the capacities for plants in excess of 100 MW from the total results in the average plant size for the remaining 1,260 plants dropping to 12 MW. There are, therefore, a great number of existing plants that meet the small hydro criteria. It would seem that the U.S. should have a considerable body of technology and technical expertise, but on the other hand, the smaller plants tend to be older plants and were specifically designed for the site. It should be noted as well that 385 MW (McDonald, 1977) of hydropower, mostly small plants, have been retired from service in the last 15 years, a trend that recent events are likely to reverse.

Initial estimates of power potential at existing non-hydropower dams indicated that about 30,000 MW and 95 billion kilowatt-hours per year (McDonald, 1977) exist at several thousand sites. These sites are among the some 50,000 dams identified in the national dam inventory prepared by the Corps of Engineers and range in size from retired small hydro plants in the New England area to major federal reclamation projects in the west. Other potential sites not identified in previous studies include irrigation canal drops (significant in the west), municipal water supply delivery systems such as in Southern California and the North Atlantic, and waste management systems such as the Chicago tunnel plan (Gladwell, Warnick, 1978; Macaitis, Schonsett, 1979). An improved resource assessment of small hydro potential and sites will be generated as a component of the Corps of Engineers National Hydroelectric Power Study activities (Institute for Water Resources, 1979). Preliminary results indicate the gross potential at existing dams lies in the 6,000 to 10,000 MW range at upwards of 5,000 sites. Since a significant portion of small hydro development is likely to have no dependable capacity, the annual energy potential is a more meaningful index of the contribution to the nations energy needs than is capacity. The gross potential annual energy at existing dams lies in the 18 billion to 25 billion kWh range, which is equivalent to a savings of 80,000 to 140,000 barrels of oil per day.

Analysis of the national dam inventory data (50,000 dams) indicates that about 1/3 of the sites have heads in the 6 to 20 foot range (considered extremely low in the "low head" literature) and about 2/3 of the dam sites have intermittent flow (inflow ceases some time during the year). Also, a number of significant physical, economic, and institutional obstacles exist that presently inhibit development of a large number of the sites. The economically attractive sites under present conditions would total significantly less than the 30,000 MW reported potential, but it is generally agreed that several hundred sites are likely to be found economically attractive for immediate development. The cost of fossil fuels is expected to continue to grow and thus increase the economic attractiveness of hydropower in general, and in particular small hydropower, such that within the next ten years, upwards of 2,000 sites could be considered as a reasonable count for the number of small hydro sites warranting serious study for implementation.

## Implementation Issues

A significant major positive feature of small hydro is that many of the important environmental issues have been previously resolved (e.g., the impoundment site exists and is presently in service). This suggests that it should be substantially less complex to plan developments, marshal support, acquire needed permits, and construct small hydro additions than to develop other new hydro projects or alternative thermal power generation plants. The lag time from conception to implementation could be as little as 3 years (Figure 2-1) compared to the often 10-15 years for major projects. The current trend in small hydro is to take advantage of the head and existing flow release patterns to avoid the environmental and legal complexities that would ensue from altering water use, modifying release patterns, and adding storage (thus increasing pools level). The inferred judgment seems to be that the complexities induced by altering existing use and release patterns to enable generation of more power and perhaps development of some dependable capacity (see glossary for definition) are not worth the time delays and added implementation complexity that would result. In effect the thrust is "let's develop what's presently lost through energy dissipation structures and get it on line quickly, since we are at least aiding in meeting near term energy requirements."

The belief that there will not be instances of important environmental issues is not realistic, however. Any alteration of the flow pattern and released water quality will require careful documentation and analysis. Also, past mitigation omissions will likely be surfaced during studies and will need to be corrected. A specific case in point is that fish passage facilities (especially for anadromous fisheries) are likely to be insisted upon for sites from which they were omitted in a prior era, and preliminary indications are that precedents exist to backup the insistence. Small hydro offers an opportunity for engineers to provide the leadership early in project development to identify and formulate solutions to potential environmental problems. The key point is to define issues early in investigations so that they may be included as a normal component of project feature planning.

## Factors Important for Feasibility

Several important issues that can be inferred from the previous discussion are pertinent to establishing the conceptual base for the feasibility guide manual. One is understanding the reasons underlying the major national attention that is focused on small hydro, an admittedly small element of the national energy array. Simply stated they seem to be the national desire to move to energy independence, the current national concern for resource conservation and use of renewable resources, the potential for quick results from public and private efforts (an increasingly rare commodity in today's world), and most assuredly, the demand for nonfirm energy (previously referred to with the tainted label "dump energy") presently valued in many areas at 15 to upwards of 40 mills per kilowatt-hour as compared to 1 to 2 mills per kilowatt-hour several years ago.

The greatest potential seems to be at existing sites with the major civil works already in place. The sites typically are in non-federal ownership (about one-half of existing hydropower plants are in non-federal ownership). The sites are often in the low head range (under 20 meters), with a significant number falling in the head ranges of less than 30 feet. The marketable output will most often only be energy with little, if any, dependable capacity. This means the value of small hydro output will be primarily due to fuel and other operating cost savings and not due to offsetting the need for new power plants to supply capacity.

The feasibility of projects is expected to be quite sensitive to site specific conditions. The value of power produced will not likely support an extensive array of ancillary features such as long transmission lines, access roads, or significant site preparation. The nature of the market area load characteristics and present generating facilities servicing the load are critical elements in valuing power output. Areas served with major fossil fuel plants, or systems with high operating cost plants operating at the margin will be more attractive for small hydro development. A significant issue of project feasibility is that investigation, design, construction management, and administration (the non-hardware elements of a project) are a major project cost burden. Figure 2-2 schematically illustrates the cost elements in small hydro projects. Contingencies, which are not shown, are normally considered as a percentage of all of the items listed, and range from 10 to 20 percent. The feasibility study itself is likely to be viewed as a significant financial burden warranting an investment type decision by the project sponsor prior to initiation of the study.

Small hydro is therefore a unique set of hydroelectric power developments with potential that exists at a relatively large number of existing sites that are mostly in non-federal ownership, primarily of low head, likely to generate "non-essential" power, and sensitive to site specific conditions, and will require investigations whose costs are a significant issue. The guide manual has been formulated to be responsive to these characteristics and to provide a foundation to encourage relatively quick, efficient formulation and assessment of attractive projects.

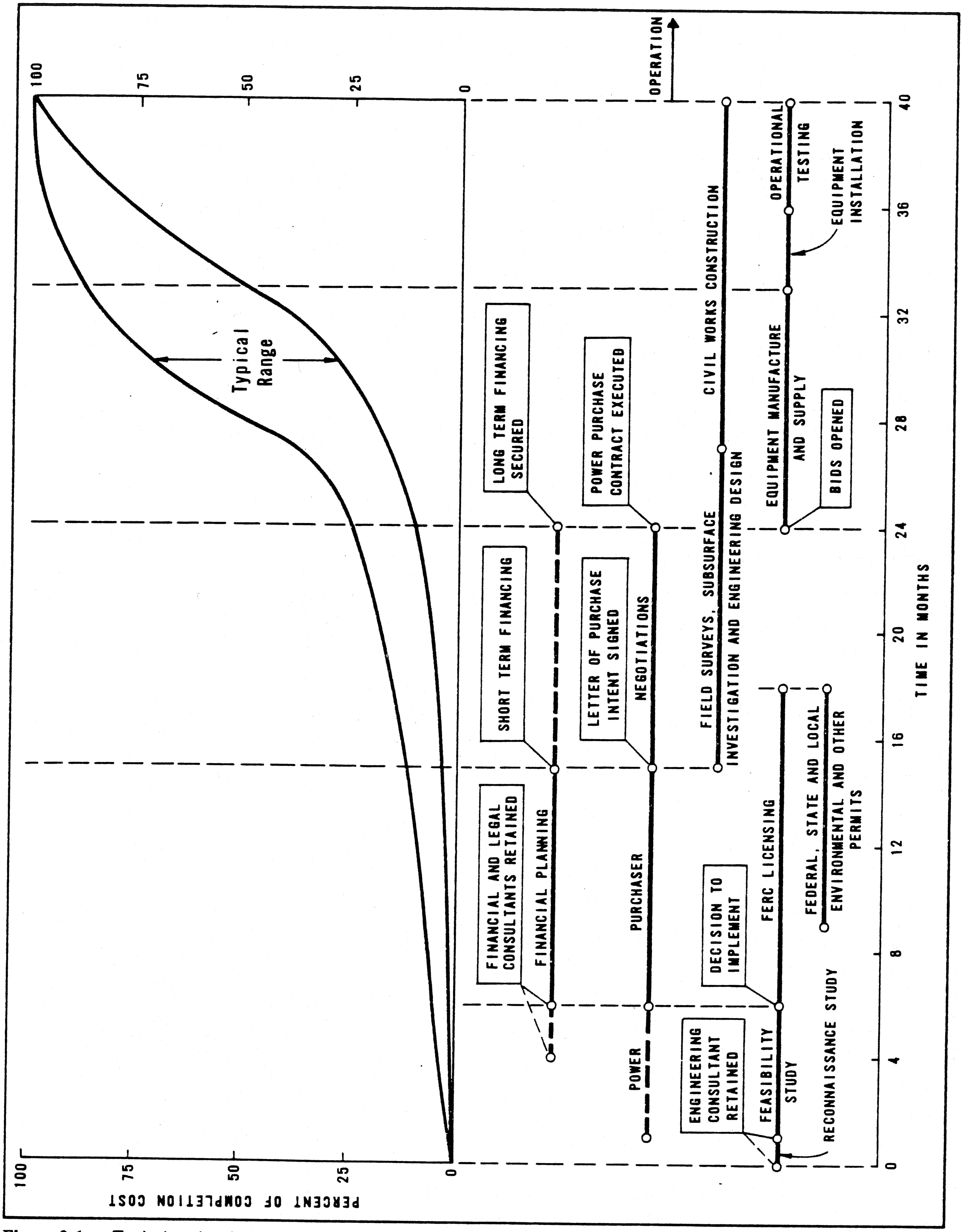



**Figure 2-1.** Typical project implementation schedule and expenditure pattern (From Volume II-Economic and Financial Feasibility)

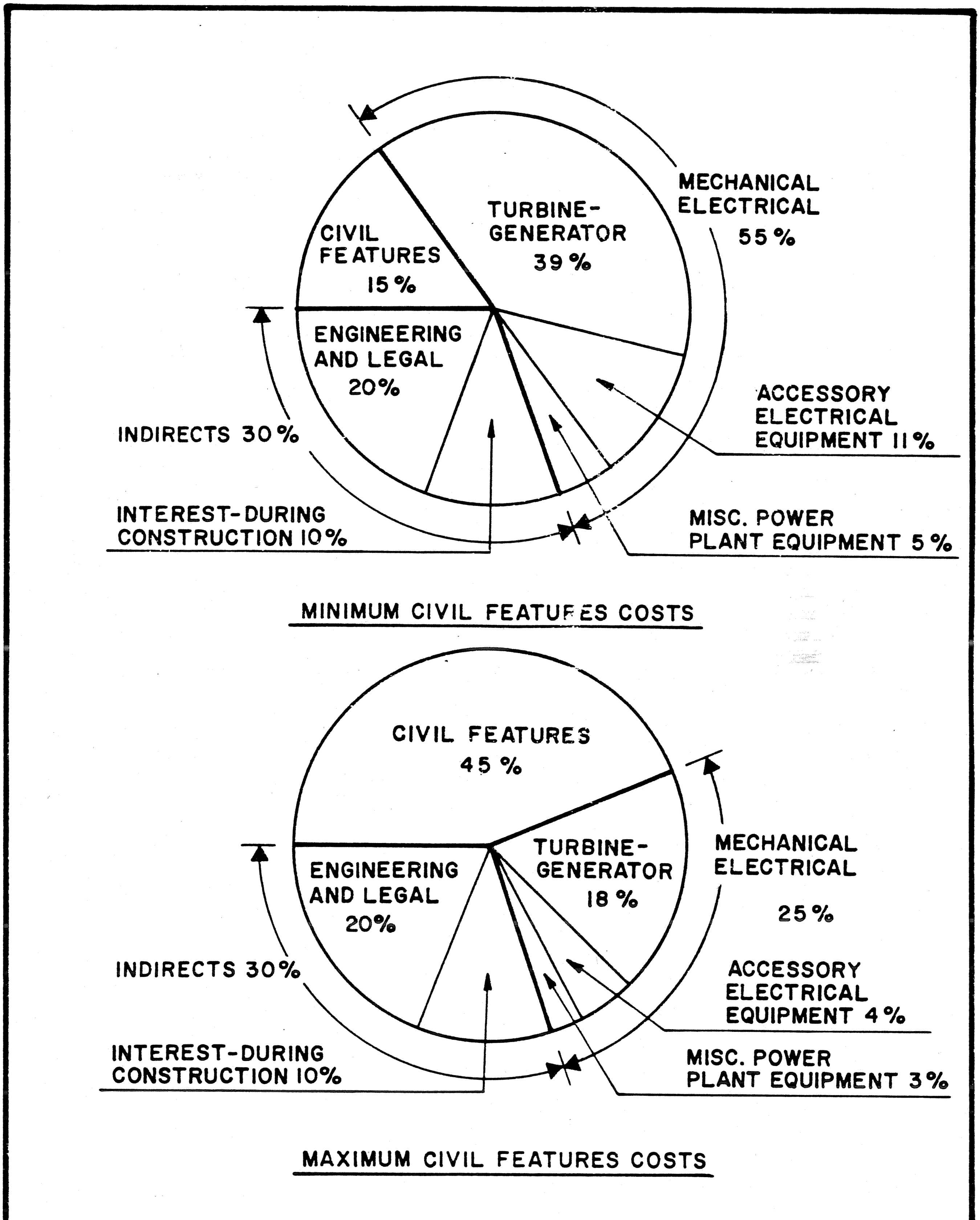



**Figure 2-2.** Cost elements of small hydro projects. (From Volume VI-Civil Features)

# SECTION 3
# PLANNING INVESTIGATIONS

**Definitions**

Several types of investigations varying in scope, detail, and intended client are performed to determine the desirability of public and private implementation of hydropower proposals. These investigations are usually referred to as planning studies. The end points of these studies are relatively easy to define; the formation of an idea or concept for a project at the beginning, and the initiation of construction at the end. Varying degrees of decisions and commitments occur in a continuous sense but normally are formally adopted at discrete decision points throughout this period. Government agencies and private organizations normally have specific steps (study types) that are standard for their purposes.

The general collective term for most of the planning studies performed prior to an implementation decision are "feasibility" studies. Other studies take place between the implementation decision point and construction initiation. This guide manual has adopted the standard sequence of preconstruction studies commonly followed in private and international practice (United Nations, 1964) and several Federal agencies. They are "reconnaissance study" (should a feasibility study be performed?), "feasibility study" (should an investment commitment be made?), and "definite plan studies" (the collective group of studies that are performed between the time of an implementation commitment and initiation of construction that result in permit applications, preparation of marketing agreements and financial arrangements, determination of design parameters, etc). Figure 2-1 schematically identified these studies in the project development and implementation sequence. The guide manual is designed to aid in the performance of the reconnaissance and feasibility studies.

The Glossary defines a reconnaissance study as ... "a preliminary feasibility study designed to ascertain whether a feasibility study is warranted" and feasibility study as ... "an investigation performed to formulate a hydropower project and definitively assess its desirability for implementation."

**Objective of Reconnaissance Study**

The performance of a feasibility study can be a significant investment in time and resources suggesting that a decision to proceed with a study should be based on a finding that a potentially viable project proposal will be forthcoming. The reconnaissance study is designed to reduce the chance of a subsequent unfavorable feasibility finding and maximize the potential for identifying and moving forward attractive projects. The reconnaissance study is therefore a relatively complete small scale feasibility investigation in which the issues expected to be important at the feasibility stage are raised (the intent is to appraise the critical issues, not formulate approaches and solutions), and to perform a first cut economic analysis. A favorable economic feasibility finding is a strong indicator that further detailed study (a feasibility study) is warranted subject to assessment of potentially critical negative issues. The finding of a reconnaissance study should be either a positive recommendation to proceed with a feasibility study and then also include a study plan and method of accomplishment, or a recommendation to terminate further investigations. The strategy for performing a reconnaissance study is first to perform a preliminary economic analysis and then identify and assess the issues that may be critical to implementation. Section 4 describes the components that are likely to be important in a reconnaissance assessment and suggests appropriate levels of work efforts.

**Objective of Feasibility Study**

The feasibility study is designed to formulate a viable small hydro project, design an implementation strategy, and provide the bases for an implementation commitment. The significant legal, institutional, engineering, environmental, marketing, economic, and financial aspects are to be defined, investigated, and definitively assessed in support of an investment decision. The feasibility study is a decision document that defines and recommends a course of action. The findings of a feasibility investigation should be whether or not a commitment to implementation is warranted, and should the finding be positive, define the steps needed to assure implemention. A positive economic feasibility finding is normally necessary for further implementation to be initiated. However, other concerns can be equally important in serving the broad public interest and the feasibility study should be performed in the modern spirit of wise natural resource management and multi-objective planning principles. Section 5 provides strategic guidance on performance of feasibility studies and suggests appropriate levels of work efforts.

# SECTION 4
# RECONNAISSANCE STUDIES

**Reconnaissance Study Tasks**

The components identified as important in reconnaissance studies are shown on Figure 4-1. The tasks include those required to perform the economic feasibility (power potential, value, cost, and site capabilities) and those that should aid in defining and assessing critical issues (authority and legal issues, site issues, facility integrity, and financial and revenue issues). Subsequent paragraphs briefly discuss the tasks shown on Figure 4-1. Table 4-1 summarizes the pertinent reference sections in the supporting volumes of this manual.

**Plan Reconnaissance Study**. The specific scope and purpose of the study should be defined and needed output products identified. The scope and purpose have been generally identified in this section of the volume, but variations in emphasis may exist, depending on project proponent (private, public) and prior studies (national, regional screenings), which should be defined. A study plan should be formulated identifying the important work tasks (e.g., refining the suggestions of this section). It is suggested that by this point at the initiation of a reconnaissance study that all volumes of the guide manual be read by the responsible participants.

**Contact Principal Agencies**. This task has been identified a bit out of context because it would logically be an element within each of several tasks. However, activities by various institutions have developed valuable information that is presently, or soon will be, available that warranted highlighting in the guide manual.

The U. S. Department of Energy (DOE) has specific programs designed to encourage the development of small hydro. The local regional office (for phone number see government section of the phone book) can provide information on up to date activities within that agency. The Idaho Operations Office, DOE, (550 Second Street, Idaho Falls, Idaho 83401) is the action office in small hydro and is active in developing an information referral service and compiling data on small hydro projects.

**TABLE 4-1**
**RECONNAISSANCE STUDY TASKS*/**
**MANUAL REFERENCE SECTIONS**

| Study Tasks | Volume | Manual Reference Section | Description |
|---|---|---|---|
| Plan Reconnaissance Study | I | 4 | Par. of same title. |
| Contact Principal Agencies | I | 4 | Par. of same title. |
| Scope Economic Evaluation | II | 4 | |
| Define Power Potential | III | 3 | |
| Assess Market Potential | II | 3 | |
| Estimate Power Output | III | 3 | |
| Develop Spillway Hydrology | III | 4 | Early paragraphs. |
| Identify Physical Works | V, VI | 1, 2 | Fig. 2-2, Vol. V. |
| Formulate and Cost Project | I | 4 | Fig. 4-2, Table 4-2. |
| Develop Cost Stream | I | 4 | Par. of Same Title. |
| Adopt Power Values | II | 3 | |
| Develop Power Benefit Stream | II | 2 | |
| Determine Economic Feasibility | I | 4 | Par. of same title. |
| Identify Critical Issues | I | 4 | Par. of same title. |
| Assess Legal/Institutional Issues | I | 4 | Par. of same title. |
| Assess Site Issues | I | 4 | Par. of same title. |
| Assess Facility Integrity | IV | 3 | Stage 1 discussion. |
| Assess Financial Issues | II | 6 | Early pages. |
| Document Reconnaissance Findings | I | 4 | Par. of same title. |

*Tasks identified are those shown on Figure 4-1 and are discussed in this section.

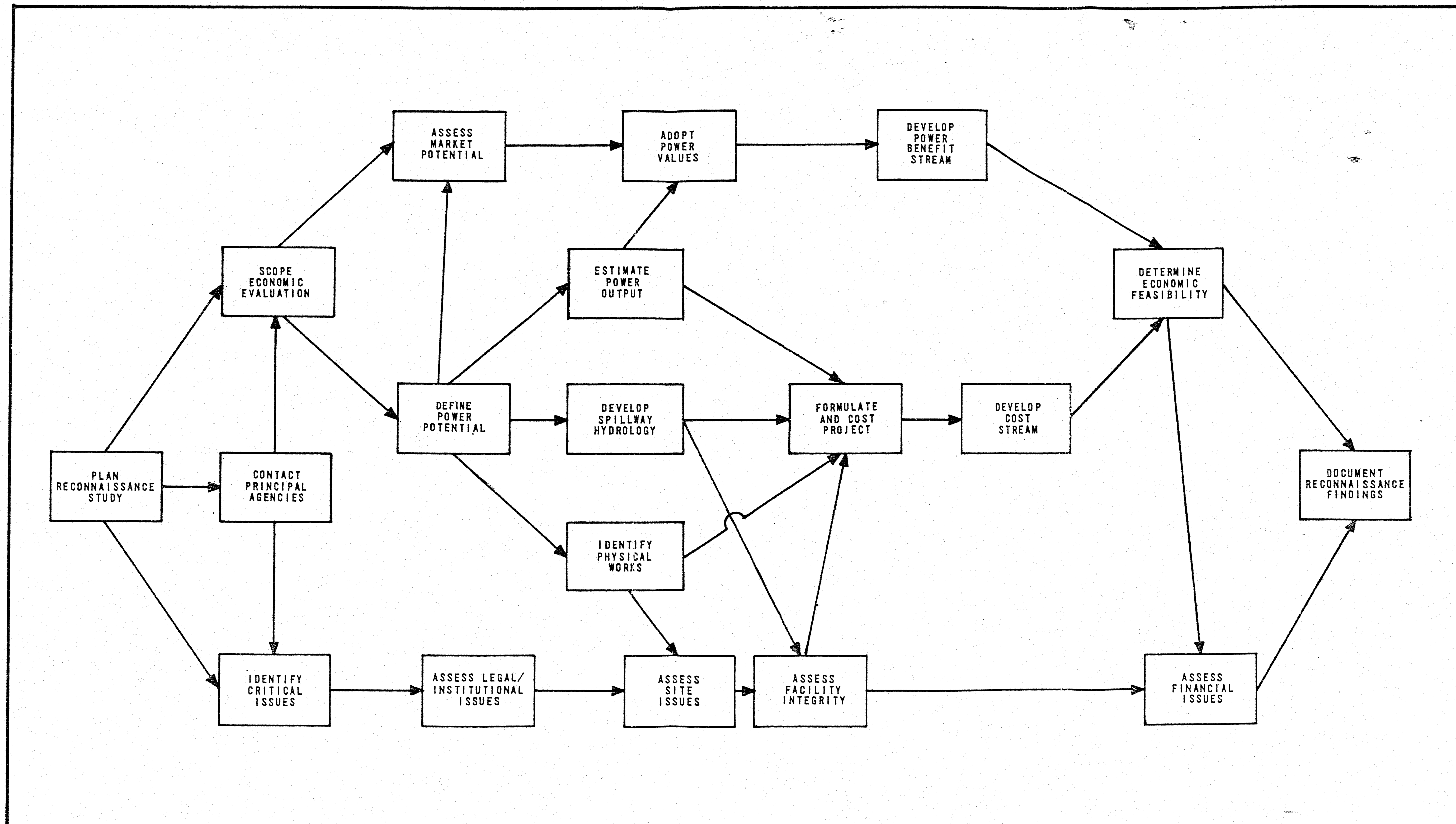



**Figure 4-1.** Reconnaisance study components

Several agencies have performed assessments of the potential for small hydro in their geographic areas - it is possible the site under investigation might exist in one of these inventories. Agencies to contact include state water (or natural resources agency) offices, regional river basin commissions, and local offices of the U.S. Bureau of Reclamation and U.S. Army Corps of Engineers. A nationwide hydropower resources assessment has been compiled as a feature of the U.S. Army Corps of Engineers National Hydropower Investigation (Institute for Water Resources, 1979). All potential sites that could be identified from reports or are in the national dam inventory are included in a computerized inventory that could provide valuable reconnaissance data. A summary of the file contents has been made available to the public. The responsible agency is the Corps of Engineers Institute for Water Resources, Kingman Building, Ft. Belvoir, VA 22060.

**Scope Economic Evaluation.** Small hydro projects are generally single purpose power projects. As such, the economic justification is based on the value of power that can be generated. If other project features are to be considered in the economic evaluation such as recreation, fish and wildlife, etc., they should be defined at this point and tasks related to their quantification formulated. See Section 4, Volume II for further discussion.

**Define Power Potential.** The value of power output from a proposed project, and the appropriate physical facilities are sensitive to the nature of the power potential. Is the plant likely to produce only energy or does it have potential for dependable capacity value as well? About how much output is likely and what is its variability? These are information items that are needed to assess market potential and provide formulation data. See Section 3, Volume III.

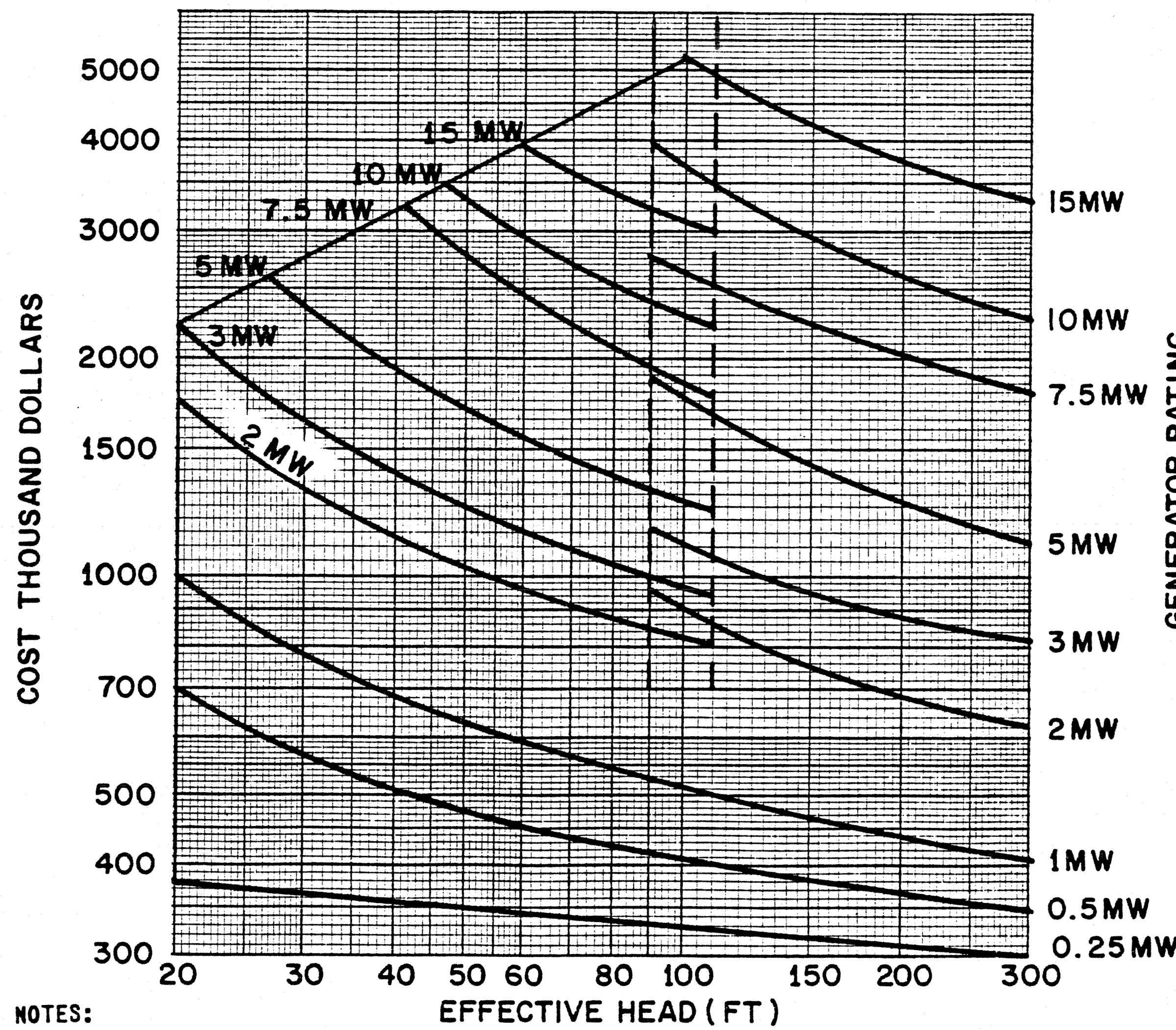
**Assess Market Potential.** Potential buyers of power output should be identified so that estimates of the value of power may be determined. Information important to determining the value of power includes: who is presently generating and selling power in the area, what types of generating equipment are in operation, and who are major customers. Purchasers could include utilities, cooperatives, private industry and other institutions. See Section 3, Volume II.

**Estimate Power Output.** The value of power output and the cost of works to produce the power are functions of the magnitude and character of output. Several project installed capacities should be investigated to estimate power potential, covering a range of likely installed capacities. Three potential sizes would seem appropriate. A mid value of installed capacity chosen to correspond to the 25% flow-exceedance value is a reasonable starting point with the other two selected at say 15% and 35% exceedance values. Computation methods described as Reconnaissance Sizing Procedures in Section 3 of Volume III provide suggested guidance. The desired product of this task is an array of installed capacities and corresponding annual energy output, indicators of the range of likely output by seasons and years (high and low flow periods), and an assessment as to the amount of capacity (if any) that might be credited as dependable. The head and flow ranges of the array are likewise needed to size and cost the power features.

**Develop Spillway Hydrology.** The flood flows that must be passed, and the present spillway capability to pass the flood events of rare occurrences are important indicators of the integrity of the existing facility. Reconnaissance estimate methods of flow determination and spillway performance analysis are contained in Section 4 of Volume III, particularly early paragraphs of the section.

**Identify Physical Works.** The power generation and appurtenant works must be suitable to the intended installation and site. A specific preliminary design is not required but sufficient formulation to define likely machine type and possible configurations are needed to assess site issues, and provide a basis for cost estimates. Introductory sections of Volume V and Volume VI provide general information; note particularly Figure 2-2, Volume V.

**Formulate and Cost Project.** Cost estimates for construction, site acquisition, operation and maintenance, and engineering and administration are needed to assess economic feasibility. To facilitate reconnaissance estimates, the charts contained in Volumes V and VI have been analyzed to develop the chart and tables contained in this section. Figure 4-2 provides a basis for estimating the major share of construction costs for items that are governed by capacity and head, e.g., turbine, generator, and supporting electrical/mechanical equipment. The chart was developed by studying the generator and powerhouse costs for a variety of turbine types for a complete set of head/capacity values. The chart is therefore the locus of least cost points for head/capacity values shown. The reader is cautioned that this chart is based on the figures contained in other manual volumes and least construction cost criteria governed so that site issues of space and configuration, and generation issues of performance ranges were not used. The chart should be adequate, however, for reconnaissance estimates. Installation of multiple units can be considered using these charts although the refinement of analysis might be questionable at this level of study. A recent paper (O'Brien, George, Purdy, 1979) suggests that multiple units may be critical to small hydro feasibility because of the goal of generating as much energy as possible from the available flow regime. Projects approaching the upper limits of small hydro capacity (15 MW) probably warrant using the charts of Volumes V and VI at the reconnaissance level of study. The remaining components needed for preparing construction cost estimates are included in Table 4-2. Other cost items that may have surfaced during study of the critical issues (access, fish passage, integrity, etc.) should be estimated at this




NOTES:

1. Estimated costs are based upon a typical or standardized turbine coupled to a generator either directly or through a speed increaser, depending on the type turbine used.
2. Costs include turbine/generator and appurtenant equipment, station electric equipment, miscellaneous powerplant equipment, powerhouse, powerhouse excavation, switchyard civil works, an upstream slide gate, and construction and installation.
3. Costs not included are transmission line, penstock, tailrace construction and switchyard equipment.
4. Cost base July 1978.
5. The transition zone occurs as unit types change due to increased head.
6. For a Multiple Unit powerhouse, additional station equipment costs are \$20,000 + \$58,000x(n-1) where n is the total number of units.
7. Data for this figure was obtained from figures and tables in Volumes V and VI.

**Figure 4-2.** Power features cost - reconnaissance

stage as well. In the absence of specific estimates for these additional items, a reconnaissance omissions allowance of up to 20% would be appropriate. The products of this task should be an array of costs for the range of installed capacities for which power estimates were prepared.

**Develop Cost Stream.** The construction cost values developed in the previous paragraph need to be gathered, organized, and arrayed to permit expeditious performance of the economic feasibility calculations. The construction costs should be escalated to the study date. Section 6 of Volume VI presents a strategy for escalating costs of civil features.

It is recommended that the cost index for "structures" be used as a composite value for all construction items for the reconnaissance cost estimates. Cost estimates are also needed for the nonphysical works cost items. An allowance for unforeseen contingencies ranging from 10% to 20% should be added to the sum of the construction costs, the value depending upon a judgment as to the uncertainties. A mid value of 15% for contingencies is appropriate in the absence of more detailed analysis. All investigation, management, engineering and administration costs that are needed to implement the project and continue its service are appropriately included in the feasibility determination. It is suggested that indirect costs for administration, engineering, interest during construction, etc., of 25% be added. Total indirect costs to be added will therefore vary between 35% and 45%.

**Adopt Power Values.** The power values needed are the value of energy that the project proponent could reasonably expect to receive for the sale of output, and if any dependable capacity is likely to be present, the value of the dependable capacity of the project. It is suggested that reconnaissance values be adopted from values solicited from the local Federal Energy Regulatory Commission (FERC) office in the case of potential sale to utilities,

**TABLE 4-2**
**MISCELLANEOUS RECONNAISSANCE ESTIMATE COSTS***
**(Cost Base July 1978)**

**PENSTOCK COST**

| Effective Head (Ft) | 10 | 20 | 50 | 100 | 200 | 300 |
|---|---|---|---|---|---|---|
| Cost Index (CI) | 960 | 480 | 200 | 110 | 55 | 35 |

Installed cost = CI x Penstock Length (ft) x Installed Capacity (MW)
Minimum Penstock Cost is $50 per linear foot.

**TAILRACE COST**

Construction Cost = $15,000 fixed plus $200 per linear foot

**SWITCHYARD EQUIPMENT COST**
(Thousand Dollars)

| Plant Capacity | Transmission Voltage 13.8 | 34.5 | 69 | 115 |
|---|---|---|---|---|
| 1 MW | 50 | 60 | 110 | 160 |
| 3 MW | 85 | 100 | 120 | 175 |
| 5 MW | 110 | 125 | 150 | 210 |
| 10 MW | 150 | 170 | 210 | 280 |
| 15 MW | 185 | 220 | 250 | 320 |

**TRANSMISSION LINE COST**
(Thousand Dollars)

| Plant Capacity | Miles of transmission line 1 | 2 | 5 | 10 | 15 |
|---|---|---|---|---|---|
| 0.5 MW | 30 | 60 | 150 | — | — |
| 5 MW | 45 | 80 | 160 | 320 | 500 |
| 10 MW | 60 | 100 | 180 | 380 | 600 |
| 15 MW | 80 | 140 | 230 | 460 | 700 |

*Data derived from Volume V (Figures 6-4 and 6-5) and Volume VI (Figure 3-1 and Table 4-2).

municipal organizations and cooperatives, or be extracted from existing rate schedules (available from the local utility office) in the case of potential sale to a private industrial buyer. A benchmark value that can often be used as the minimum value for energy is the fuel replacement cost that is obtainable from the nearest FERC regional office. A generous value seems appropriate in light of presently escalating fuel and operations costs. Generalized power values are expected to be published as part of the Corps National Hydropower Investigation (Institute for Water Resources, 1979). Current values (1979) for energy in the range of 20 to 40 mills per kilowatt-hour are considerable reasonable. Section 3, Volume II discusses power values in detail.

**Develop Power Benefit Stream**. The power generation benefits from the proposed project are the sum of the energy value times the energy production and the capacity value times the estimated dependable capacity (if any). In the instance of a private purchaser, the difference in their power bill with and without the proposed project is the benefit. The project benefit stream is the annual array of power benefits (plus other project benefits if determined to be appropriate). Project benefit streams should be prepared for the several installed capacities under study. See Section 2, Volume II.

**Determine Economic Feasibility**. Economic feasibility is positive when the stream of benefits exceeds the stream of costs. It is suggested that the Internal Rate of Return method of characterizing project feasibility be employed. The Internal Rate of Return is the discount rate at which the benefits and costs are equal, e.g., the discount rate at which the benefit to cost ratio is unity. This avoids the need at the reconnaissance stage to adopt a discount rate and thus provides an array of economic feasibility results. See Economic Analysis Cost Needs paragraph of Section 5 for additional commentary on costs, benefits, discount rates, evaluation periods, and cost escalation. The analysis should be performed for each of the several installed capacities under study. The alternative is to compute a benefit cost ratio using the discount rate that represents the minimum attractive rate of return for the project proponent. A value in the 9% range has been used in many studies for special districts and agencies in the public sector and a value of 17% in the private sector.

An example computation and display is included in Figure 4-3. Should the outcome of the economic feasibility test appear uncertain, simple sensitivity analysis based on the important variables (power values/fuel costs, amount of energy/capacity, etc.) could significantly contribute to narrowing the band of uncertainty. Use of values contained in Table 5-2 of Section 5 greatly facilitates study of the effect of cost and value escalation on project feasibility.

**Identify Critical Issues**. The potentially critical issues should be identified and actions required to clarify their importance defined. The issues have been generally identified in this section but important variations may exist depending on project proponent, prior studies, location, etc. The issues that are likely to emerge are primarily related to legal and institutional factors, physical factors focused on the site, integrity of the existing facilities, and financial and revenue capabilities.

**Assess Legal/Institutional Issues**. An assessment is needed at the reconnaissance stage to define the mechanisms that are likely to be needed to implement a project (e.g., site ownership, legal authority to develop/sell power, access to power grids) and to appraise the actions needed to overcome obstacles, should they exist. Several studies are nearing completion by the Department of Energy (Brown, 1979) that will aid in issue definition. The finding required here is whether and to what degree (qualitatively) impediments to development exist so they may be planned for in the feasibility investigation, should the reconnaissance findings prove to be positive.

**Assess Site Issues**. A site visit should be considered essential at this stage for (rare exceptions excluded) all reconnaissance investigations of projects. Sketches and drawings may be made and/or existing ones verified defining space for plant siting, terrain and construction features, access, operational status of facilities, and other items pertinent to the physical arrangement of the site, construction of the needed works, and transmission of the power to distribution facilities. The site visit by responsible professionals should be coordinated to provide for a reconnaissance stage integrity assessment as well.

**Assess Facility Integrity**. The integrity of the site to satisfactorily serve as a power facility and be safe from failure could be a major issue in power addition proposals for many old existing impoundments. Volume IV, especially the discussion of Stage 1 investigations described in Section 3, provides guidance on the needed assessment. See also previous paragraph entitled Spillway Hydrology. The Corps of Engineers (U.S. Army Corps of Engineers, 1975) has been charged with preparing an inventory of existing dams (estimated at 50,000) and performing preliminary assessments of the integrity of certain sites classified as critical. The local offices of the Corps of Engineers can provide information on the current status of integrity investigations, and if a study has been completed, may provide a copy of the report. The fact that a facility exists and continues to function (e.g., has not yet failed) is not conclusive evidence that the dam is safe. The potential impacts of increased stresses from constructing a powerhouse addition should be identified and appraised.

**Assess Financial Issues**. Sufficient funds must be raised to construct the plant, and adequate flow of revenues generated to provide for maintaining the plant in service, retiring loans, and producing a profit to the developer. The nature of likely financing needs to be defined, potential marketing and revenue arrangements described, and perhaps most important at this recon-

PLANT CHARACTERISTICS:

RUN OF RIVER

| | | | |
|---|---|---|---|
| Head | = 90 feet | Penstock | = 115 feet |
| Capacity | = 8 MW | Transmission Line | = 2.5 miles @ 34.5 kV |
| Efficiency | = 90% | Economic Life | = 50 years |
| Dependable Capacity | = 0 MW | Evaluation Date | = July 1979 |
| Tailrace | = 250 feet | Average Yearly Energy Generated | = $35 \times 10^6$ kWh |

INVESTMENT COST: ($1,000)

| | | |
|---|---|---|
| Turbine, Generator and Civil (Figure 4-2) | | 2,000 |
| Additional Station Equipment (Multi-Unit) | | None Required |
| Penstock (Table 4-2) | (128 x 115 x 8) | 118 |
| Tailrace (Table 4-2) | (15,000) + (200 x 250) | 65 |
| Switchyard Equipment (Table 4-2) | (8 MW @ 34.5 kV) | 152 |
| Transmission Line | (8 MW @ 2.5 miles) | 105 |
| Dam Rehabilitation (Integrity) | | None Required |
| Other (Access, Fish Passage, Miscellaneous Site Construction) | | None Required |
| SUBTOTAL | | 2,440 |
| Escalation (July 78 to July 79 - Figure 6-1, Vol. VI - Ratio: 2.52/2.28) | | 2,697 |
| Contingencies at 10%-20% | (Used 15%) | 405 |
| SUBTOTAL | | 3,102 |
| Indirect @ 25% | | 776 |
| TOTAL INVESTMENT COST | | 3,877 |

ANNUAL COST: ($1,000)

Annualized Investment Cost is a function of discount rate and economic life of a project and is computed by multiplying the Total Investment Cost by the Capital Recovery Factor for the discount rate and economic life selected. See Table Below

Operation and Maintenance (O&M) Cost = ($20,000 Minimum or 1.5%-4%) (Used 3%) 116

TOTAL ANNUAL COST (Sum of Annualized Investment Cost and O&M Cost) = See Table Below

BENEFIT ESTIMATE:

Capacity Benefit (Dependable Capacity x Value of Capacity) = None

Energy Benefit (Average Annual Energy Generated x Value of Energy) = See Table Below

TOTAL ANNUAL BENEFIT (Sum of Capacity Benefit and Energy Benefit) = See Table Below

COST AND BENEFIT COMPUTATION TABLE

| DISCOUNT (INTEREST) RATE *(%)* | CAPITAL RECOVERY FACTOR | ANNUALIZED INVESTMENT COST[1] *($1,000)* | TOTAL ANNUAL COST[2] *($1,000)* | BREAK EVEN ENERGY VALUE[3] *(Mills/kWh)* | TOTAL ANNUAL BENEFIT[4] *($1,000)* | NET BENEFIT[5] *($1,000)* | B/C RATIO[6] |
|---|---|---|---|---|---|---|---|
| 12 | .12042 | 467 | 583 | 16.7 | 770 | 187 | 1.32 |
| 14 | .14020 | 544 | 660 | 18.9 | 770 | 110 | 1.17 |
| 16 | .16010 | 621 | 737 | 21.1 | 770 | 33 | 1.04 |
| 18 | .18005 | 698 | 814 | 23.3 | 770 | -44 | 0.95 |
| 20 | .20002 | 775 | 891 | 25.5 | 770 | -121 | 0.86 |

NOTES:

[1] Capital Recovery Factor x Total Investment Cost ($3,877).

[2] Annualized Investment Cost + O&M Cost ($116).

[3] Total Annual Cost ÷ Average Annual Energy Generated ($35 \times 10^6$ kWh).

[4] Average Annual Energy Generated ($35 \times 10^6$ kWh) x Value of Energy (taken as 22 mills/kWh) plus the Capacity Benefit (equal to zero for this example).

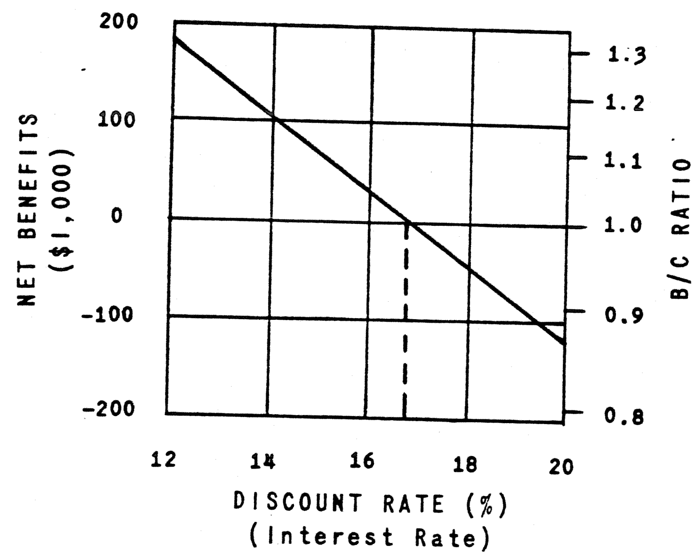
[5] Total Annual Benefit ($770) - Total Annual Cost.

[6] Total Annual Benefit ($770) ÷ Total Annual Cost.

**Figure 4-3.** Reconnaissance economic feasibility example

INTERNAL RATE OF RETURN:

The Rate of Return on Investment is the interest rate at which the present worth of annual benefits equals the present worth of annual costs (Net Benefits equal to zero or Benefit/Cost Ratio equal to unity). The internal Rate of Return is 16.8%.




BREAK EVEN ENERGY VALUE:

A similar alternative return type graph is presented here based on the concept of the Break Even Energy Value. This is the value of energy (mills/kWh) which makes annual costs equivalent to the annual return. It is determined by dividing the Average Yearly Generation (kWh) into the Total Annual Cost ($) for each discount rate selected as shown in the table above. At 22 mills/kWh, the Rate of Return is identical to that derived above.

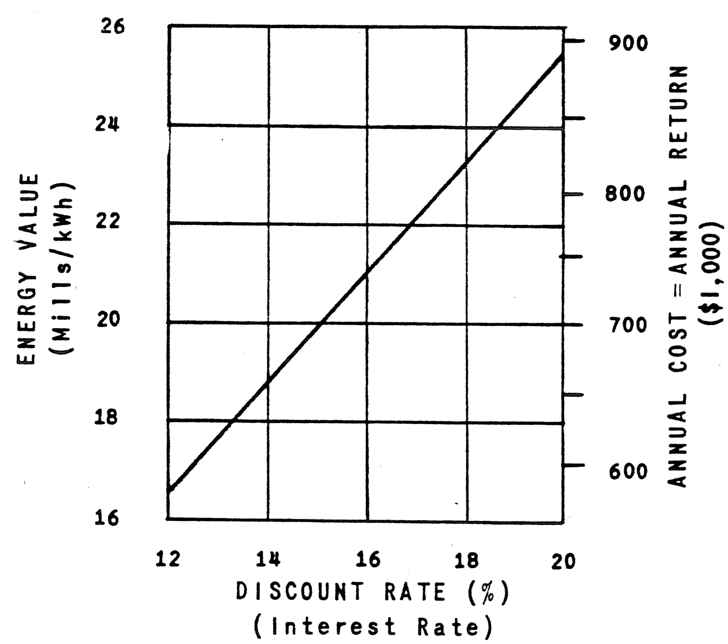



**Figure 4-3** continued. Reconnaissance economic feasibility example

naissance stage, the probable cost of capital (interest rate on financing) determined. The early pages of Section 6, Volume II provide guidance on defining financial issues.

**Document Reconnaissance Findings**. The findings of the reconnaissance investigation should be documented for study by responsible authorities (public officials, boards of directors, private investors, etc.); supporting studies, facts, and references described and codified to expedite performance of further studies; and should the finding be positive, a plan of action for the next steps outlined for execution by the project proponent. The decision to either proceed with a feasibility investigation or terminate further serious study of the potential project concludes the reconnaissance stage of project investigations.

### Time, Cost, and Resources for Reconnaissance Studies

The time, costs, and manpower resources required to perform reconnaissance studies for small hydroelectric power plants will vary depending on expected plant size, site conditions, specific scope and depth of study, and availability of information (prior resource assessments and screening studies).

The paragraph of the above title in Section 5 provides general guidance on the expected range of costs for feasibility studies. It concludes that a multiplier of 2.5% of estimated construction cost is a reasonable value for planning purposes. Since reconnaissance studies are in fact mini-feasibility studies, a value of 10% of feasibility cost seems reasonable. Reconnaissance study costs should therefore fall in the range of .15% to .3% of estimated construction cost. A reconnaissance study for a 1 MW plant might cost approximately $3,000 (or about 10-15 man-days) and require 15 to 30 days to complete, and for a 15 MW plant, perhaps $12,000 (45 to 60 man-days) and require 45 to 90 days. The participating professionals would likely include civil, mechanical, and electrical engineers, and power economist for larger proposed projects. Reconnaissance investigations of smaller projects may require more versatility in fewer professionals such as an experienced engineer and economist.